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The Massive Star Content of Circumnuclear Star Clusters in M83

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Abstract. The circumnuclear starburst of M83 (NGC 5236), the nearest such example (4.6 Mpc), constitutes an ideal site for studying the massive star IMF at high metallicity ($12+\log[\text{O}/\text{H}]=9.1\pm0.2$, Bresolin & Kennicutt 2002). We analyzed archival *HST*/STIS FUV imaging and spectroscopy of 13 circumnuclear star clusters in M83. We compared the observed spectra with two types of single stellar population (SSP) models, semi-empirical models, which are based on an empirical library of Galactic O and B stars observed with *IUE* (Robert et al. 1993), and theoretical models, which are based on a new theoretical UV library of hot massive stars described in Leitherer et al. (2010) and computed with WM-Basic (Pauldrach et al. 2001). The models were generated with Starburst99 (Leitherer & Chen 2009). We derived the reddenings, the ages, and the masses of the clusters from model fits to the FUV spectroscopy, as well as from optical *HST*/WFC3 photometry.

1. Observations

M83 is a southern, nearly face-on, grand-design spiral galaxy, hosting an arc-shaped circumnuclear starburst of ~ 200 pc in length and ~ 35 pc in thickness. The starburst is composed of several dozen clusters, which are located within a 200 pc of M83's optical nucleus. We analyzed 1200-1700 Å 52"×2" slit spectroscopy in for nine bright compact clusters, as well as 1200-1700 Å slitless spectrograms, for four additional clusters, all within M83's circumnuclear starburst. The FUV data and their analysis are described in Wofford et al. (2011). We compared the cluster ages and masses derived from the FUV spectroscopy with values obtained from optical *HST*/WFC3 photometry and derived as described in Chandar et al. (2010).

2. Model Spectra

Bresolin & Kennicutt (2002) ruled out the possibility that star formation within individual clusters proceeded continuously in the circumnuclear starburst of M83. Therefore, we fitted our cluster spectra with SSP models. Figure 1 shows the age evolution of SSP models from 1 to 20 Myr for models based on the empirical and the theoretical stellar libraries, hereafter referred to as the semi-empirical and the theoretical models, respectively. The semi-empirical and theoretical models differ below 1240 Å because of the presence of Galactic interstellar Ly α but agree rather well in the range 1240-

1700 Å, except for the O V 1370 Å line, which is stronger in the theoretical models at ages younger than ~2 Myr, and the Si IV 1400 Å feature, which is stronger in the semi-empirical models at ages 3 and 4 Myr. Note that the empirical library is contaminated with interstellar lines.

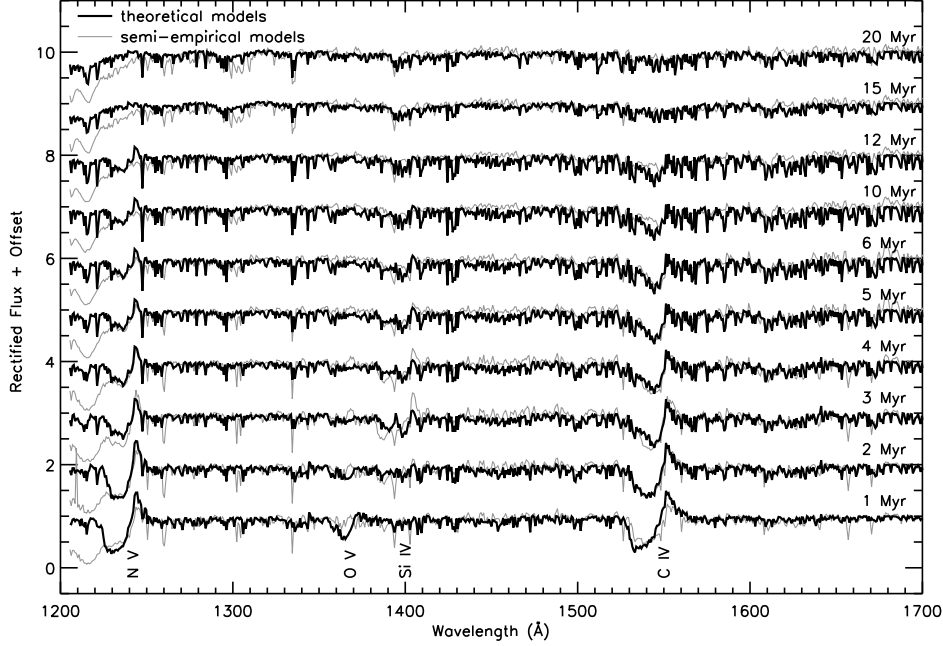


Figure 1. Evolution of SSP model spectra with time. The theoretical models are shown in black and the semi-empirical models are shown in grey. The models correspond to a metallicity of $Z = 0.020$ and a Kroupa IMF from 0.1-100 M_{\odot} .

3. Procedure

3.1. Reddening

We corrected the observed spectra for Galactic extinction based on the maps of Schlegel et al. (1998) and the extinction curve of Fitzpatrick (1999). We then fitted the FUV continuum with a power law of the form $F \sim \lambda^{\beta}$ and assumed that any deviation of β from the expected value for a dust free starburst (-2.6) was due to reddening. We used the obscuration law of Calzetti et al. (2000) to deredden the spectrum until $\beta = -2.6$ was reached.

3.2. Spectroscopic Ages, Metallicity, and IMF

Figure 1 shows the sensitivity of the N V 1240, Si IV 1400, and C IV 1550 profiles to the cluster age. M83's starburst metallicity is intermediate between $Z = 0.020$ and $Z = 0.040$, but the age estimates from models with these two metallicities are very similar. Our clusters showing strong P-Cygni profiles in N V 1240, Si IV 1400, and C IV 1550 are consistent with having formed stars more massive than 30 M_{\odot} . The presence of Si IV and C IV absorption in the rest of clusters (assuming that it is not

interstellar), suggests the presence of at least some B stars. This is illustrated in Fig. 2, where the observed spectra of clusters 1 and 10 are compared against models having upper mass limits of 10, 30, 50, and 100 M_{\odot} . We derived spectroscopic ages for all the clusters in our sample by fitting their FUV spectra with models having a metallicity of $Z = 0.020$ and a Kroupa IMF from 0.1-100 M_{\odot} . We found the best fit model by giving the most weight to N V 1240, Si IV 1400, and C IV 1550.

3.3. Spectroscopic Masses

The spectroscopic mass of each cluster was derived from the mean luminosity of the observed FUV continuum.

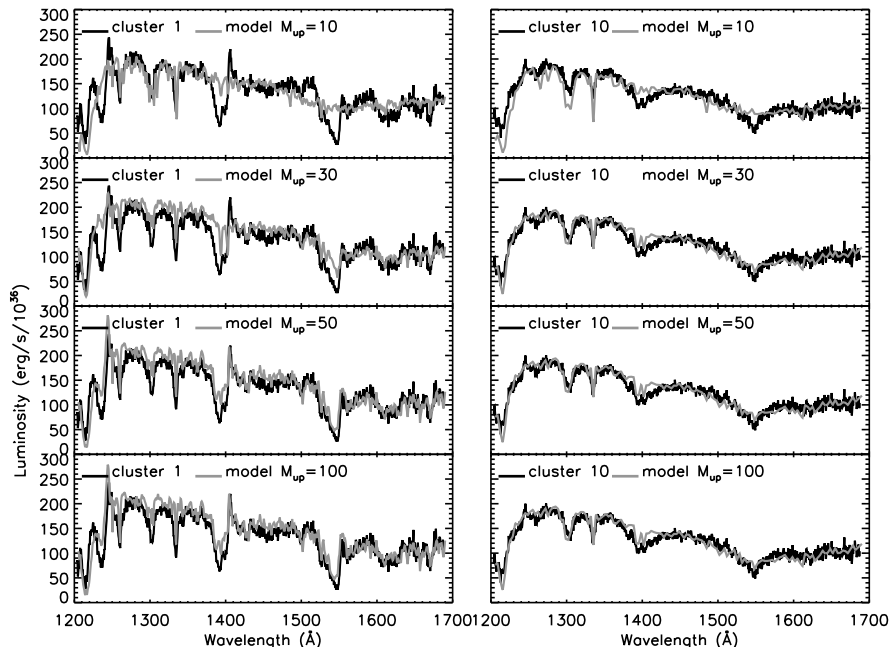


Figure 2. Observed spectra of clusters 1 and 10 (black curves) versus semi-empirical models corresponding to different upper mass limits to the IMF, $M_{up} = 10, 30, 50,$ and $100 M_{\odot}$ (grey curves). The metallicity of the models is $Z = 0.020$. The ages of clusters 1 and 10 are ~ 4 Myr and ~ 12 Myr, while their masses are $\sim 3 \times 10^4 M_{\odot}$ and $\sim 10^5 M_{\odot}$, respectively.

4. CLUSTER PROPERTIES

4.1. Masses

Optical photometry provides more leverage for determining the stellar mass than FUV spectroscopy. Therefore, our photometric masses (M_p) are more reliable than our spectroscopic masses. Our most massive cluster has $M_p = 3.1 \times 10^5 M_{\odot}$, which is comparable to the virial mass of the ionizing cluster of 30 Doradus, NGC 2070 ($4.5 \times 10^5 M_{\odot}$, Bosch et al. 2009). According to Larsen (2010), young star clusters with masses larger

than $10^5 M_{\odot}$ can last an age comparable or exceeding the age of the universe. Therefore the latter cluster could be a globular cluster progenitor, while two other clusters, which have $M_p \approx 10^5 M_{\odot}$, are just in the limit. One cluster has $M_p = 4 \times 10^3 M_{\odot}$. Unfortunately, its spectrum is too noisy to reliably say whether stars more massive than $30 M_{\odot}$ have formed in it. The rest of clusters have M_p of a few $\times 10^4 M_{\odot}$.

4.2. IMF

Our clusters with strong P-Cygni profiles have $M_p \sim 10^4 M_{\odot}$, seem to have formed stars with masses $> 30 M_{\odot}$, and are consistent with a Kroupa IMF from 0.1-100 M_{\odot} . The rest of clusters are consistent with having formed at least some B stars.

4.3. Ages

The spectroscopic ages from semi-empirical and theoretical predictions are within a factor of 1.2. The spectroscopic and photometric ages agree at a similar level. Our ages agree with those derived from *HST*/WFPC2 photometry by Harris et al. (2001), except for clusters 6, 7, and 10, which are older than 6 Myr in our case. Our ages for clusters 1-3 agree with the ages of region A derived from STIS FUV spectroscopy by Bresolin & Kennicutt (2002). The clusters are ~ 3 -20 Myr old and were not all formed at the same time. We found no age gradient along M83's starburst, in disagreement with Puxley et al. (1997) and Díaz et al. (2006).

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